P Note #486

S. Y. Hsueh
10/2/1989

Summary of Deceleration Studies Aug.15 to Sep. 15, 1989

I. Ramps above the transition energy

The dipole bus ramp was fixed to that generated in the 1988 deceleration study. The RF frequency ramp was adjusted to keep the beam in the center of the beam pipe. We normally took a reference BPM orbit at 8834 MeV/c. We then compared the orbits at other energies to the reference orbit and adjusted RF frequency to reduce the $\Delta p/p$ calculated by the BPM program (console program P49) to zero.

The quadruple ramps were adjusted to keep the tune constant. We used console program P103 for adjusting the tunes. We later found out that this procedure changed the dispersion at the zero dispersion region. It increased from 0 m at 8834 MeV/c to 1 m at 8500 MeV/c and was constant below 8500 MeV/c. We fixed this by adding 20 A to the A:LQ ramp.

There was no serious attempt to correct the closed orbit . The aperture was measured at various energies. The measurements were tabulated in table I.

TABLE I

Momentum (MeV/c)	A_x (mm-mrad)	A_y (mm-mrad)
8834	10.7π	4.43π
6534	5.8π	5.32π
5894	6.3π	4.46π
5574	4.9π	4.96π
5254	8.6π	5.21π

The deceleration efficiencies from 8834 MeV/c to before transition crossing (5174 MeV/c) are summarized in table II in reverse chronological order. The table includes all the decelerations done after the ramps were fixed. The deceleration control program was console program P81. The ramp file was file 10. The efficiency ranges from 99.5% to 94.6%. It is correlated strongly with the transverse beam size at the 8834 MeV/c.

TABLE II

Beam current (mA) at 8834 MeV/c	Beam current (mA) at 5174 MeV/c	Efficiency
7.03	6.76	96%
5.4	5.36	99%
7.125	7.09	99.5%
7.72	7.57	98%
6.63	6.27	94.6%
8.025	7.76	96.7%

II. Transition crossing

The γ_t of the machine was measured to be 5.44. To cross the transition, we stopped the deceleration above the transition at 5174 MeV/c (γ=5.60). The procedure started with debunching the beam at 5174 MeV/c. The quadruple buses (A:LQ, A:QT, A:QDF, A:QSF1, and A:QSD) were then ramped to change the γ_t of the machine. The A:LQ was ramped from 711.3451 Amp to 745.3452 Amp. This changed the γ_t from 5.44 to 6.01. The other quadruple buses were ramped to keep the tunes constant. The η ($=1/\gamma^2-1/\gamma_t^2$) changed from -2×10^{-3} to 4×10^{-3}. It is clear from the figure 1 that η changed sign. The time duration of the γ_t ramp is 16 sec. No momentum blow up was observed. The beam was then cooled before re-bunched to decelerate further. The cooling usually took half an hour. The efficiencies of transition crossing are summarized in table III. About half of the beam loss happened during the half-hour cooling.

TABLE III

Beam current (mA) above transition	Beam current (mA) below transition	Efficiency
6.76	6.22	92%
5.36	5.2	97%
7.09	6.81	96%

III. RF and the below transition ramp

In figure 2 we show the RF voltage (V_{rf}) required for constant bucket deceleration. The maximum advertised V_{rf} delivered by ARF-1 and ARF-3 are 50 KV and 4 KV. It is clear that ARF-1 runs out of RF voltage before reaching J/Ψ. It is for this reason we used ARF-3 this time. The synchrotron frequency is much lower with ARF-3. At 8834 MeV/c, the synchrotron frequency is 31 Hz if V_{rf} = 3KV. The synchrotron frequency was typically ≈ 1 KHz with ARF-1.

We found out there was a bad dipole oscillation near transition energy. Figure 3 show the broken-up bunch caused by the dipole oscillation above the transition at $\eta = 1\times10^{-3}$. We tried different combinations of η and V_{rf}. We found that larger η and V_{rf} were more desirable. The data was consistent with that dipole oscillation was driven by low frequency (<10 Hz) noise.

The procedure for deceleration below transition started with bunching the beam with V_{rf} = 3KV. The synchrotron frequency was 18 Hz given that $\eta = -4\times10^{-3}$ and V_{rf} = 3KV. The fact that we start deceleration with V_{rf} = 3KV means we run out of V_{rf} very soon. Between just below transition (5174 MeV/c) and J/Ψ (3994 MeV/c) we had to stop at 4714 MeV/c to cool the beam to reduce the longitudinal emittance. We did only one deceleration to 3994 MeV/c. The loss between 5174 MeV/c and 4714 MeV/c was negligible. Between 4714 MeV/c and 3994 Mev/c we lost ≈ 40% of the beam. This is not unexpected since the quadruple ramps were not corrected between 4714 MeV/c and 3994 Mev/c. At 3994 MeV/c we found out that horizontal tune was too close to 0.6.

IV. Cooling

We phased the cooling system at 8834 MeV/c and 6900 MeV/c. We derived d(cooling time delay)/d(revolution period) from these two data points, .

	d(cooling time delay)/d(revolution period)
Horizontal betatron cooling	0.34144
Vertical betatron cooling	0.31984
$\Delta p/p$ cooling	0.502778

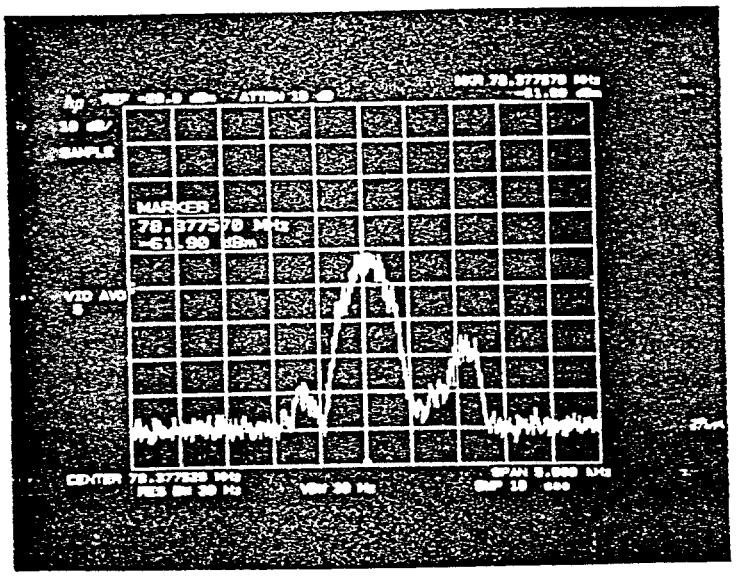
They are consistent with that the distance between betatron cooling pick-up and kicker are $\approx$ 1/3 around the ring and that $\Delta p/p \approx 1/2$.

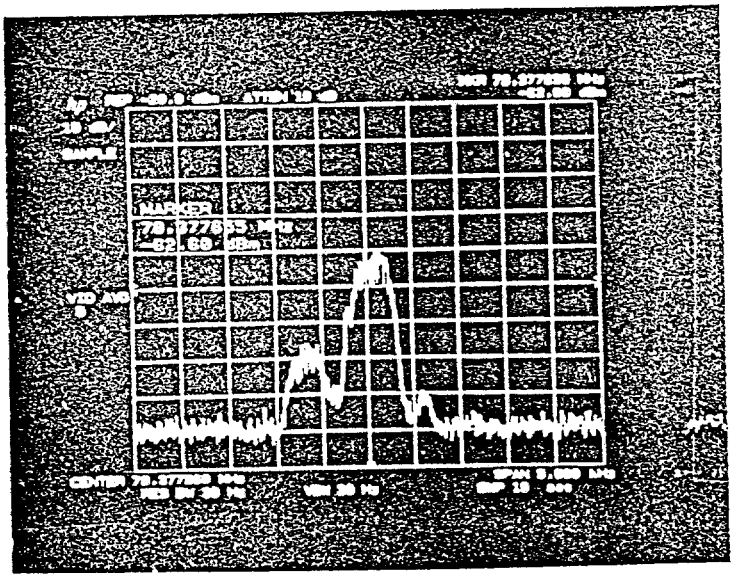
All three cooling systems were demonstrated to work at various energies above transition and just below transition at 5174 MeV/c.

V. Conclusion

We demonstrated that we can decelerate to J/Ψ with $\approx$ 60% efficiency. It is quite possible we can improve the efficiency to 90% after we correct the ramps below 4714 MeV/c next run. We still need to find the longitudinal instability threshold at the transition (η=0) and demonstrate that we can bring 30 mA to below the transition.

Longitudinal Schottky

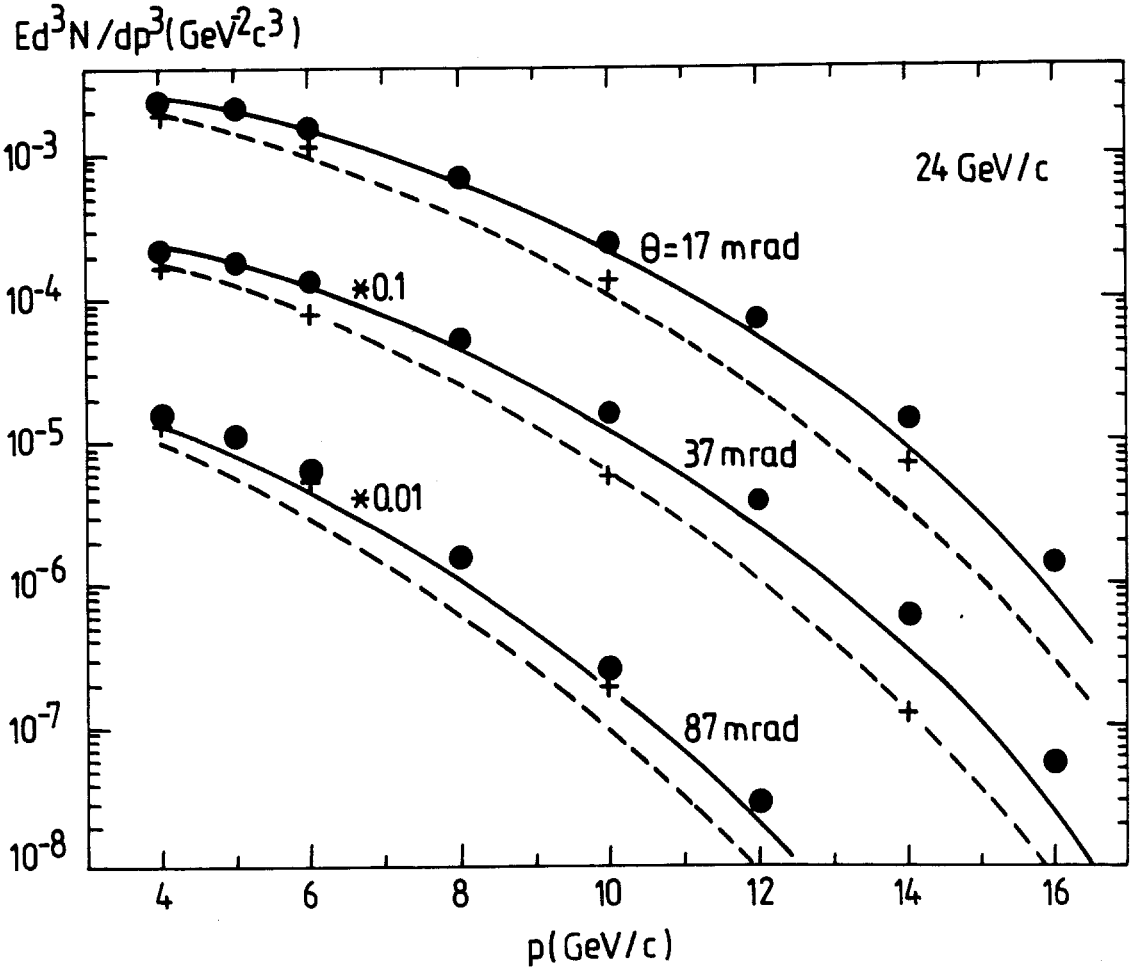




before γ_t jump

after γ_t jump

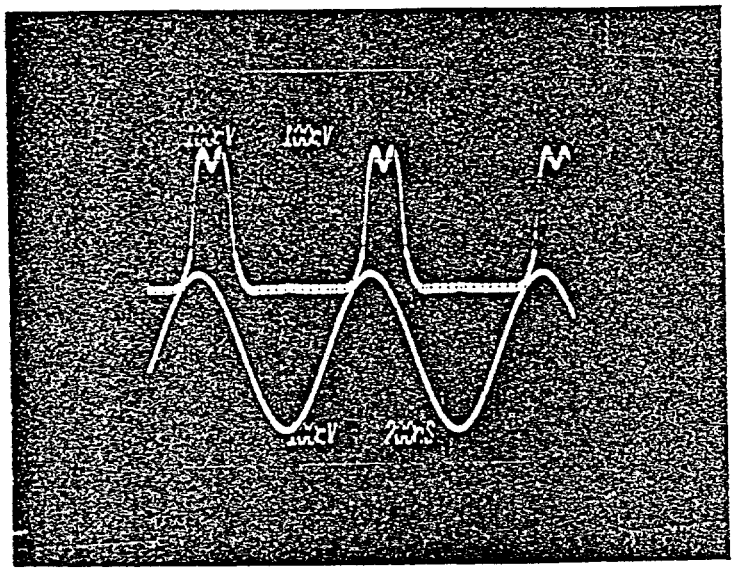
Figure 1.



● } Be + } Pb

Symbols experiment

Curves - MARS12



← bunch

← RF

picture taken after ~~decc~~ stopped deceleration at 5094 MeV/c.

Figure 3.